# APPARATUS AND METHOD WITH SPECIFICALLY PROVIDED DEVICE FOR AUTOMATIC BURST DETECTION IN BLOW-MOULDED CONTAINERS

## DESCRIPTION

### Background of the Invention

The present invention refers to an apparatus and a method for the production of hollow plastic articles, or plastic containers, in particular bottles, in which use is made of a specifically provided device adapted to identify bottles that have possibly been blow-moulded in a faulty manner and must therefore be rejected.

Although reference will be made in the following description, mainly for reasons of greater descriptive convenience, to an apparatus for blow moulding bottles of plastic material, it will be appreciated that the present invention shall be understood as applying also to other kinds of plants and processes, as far as these fall within the scope of the appended claims.

Largely known in the art are plants and methods for blow moulding plastic bottles that are obtained by filling with gas under pressure

appropriately heated plastic semi-processed elements, which are generally known by their technical name of "parisons" or "preforms" in the art.

Plants of such a kind are for instance described in the European patent application no. 96114227.0 of this same Applicant, as well as in the various patent publications cited therein.

It is rather largely known in the art that, during the preform blow-moulding process, the possibility is quite often given that (owing to a number of most varied reasons, which on the other hand shall not be discussed here owing to them not having any relevance to the present invention ) some production irregularities or disturbances may occur to such an extent as to cause some preforms, in a random sequence thereof, to expand in an incorrect manner. Additionally, some preforms are blow-moulded regularly, up to the point that they may even burst either before reaching their final shape or immediately thereafter, while they still dwell inside the blow-moulding die.

Furthermore, the possibility also arises that the same preforms turn out to be already cracked and/or defective even before that the actual blow-moulding process takes place, so that it is practically impossible for the same preforms to be blown, even partially, to the final shape thereof.

When such an event occurs, the blow-moulding plant goes on operating, even when the bottles burst. Therefore, some bottles that fail to be completed continue to be transported in their form of fully useless rejects, on the subsequently provided conveyance line together with the correctly produced bottles. Additionally, together with the correctly produced bottles, they are eventually collected in appropriate storage bins or similar containers before being sent to final utilization.

As far as this particular step is concerned, the need therefore arises for either manual or mechanical and partly automated means to identify

possible faulty bottles and remove them from the conveying, collecting and storage means as described above.

Such an operation does of course generate corresponding production costs and charges, which are quite frequently fully unacceptable in an industrial environment that is subject to a high extent of pressure in terms of manufacturing competition. It anyway introduces a complication in the manufacturing process, since it necessarily implies an addition of auxiliary operations that must be carried out by appropriate operators, usually on an off-line basis.

In an attempt to find a remedy for such a situation, the patent application PCT/EP 01/01571, filed by this same Applicant with the title "BLOW-MOULDING PLANT WITH APPARATUS FOR AUTOMATIC BURST DETECTION IN BLOW-MOULDED CONTAINERS", describes an apparatus and a method for identifying bottles which have failed, i.e. burst during the blow-moulding process.

For greater convenience, simplicity and brevity in this description, direct reference should therefore be made to such a document for a better insight in the disclosure thereof.

Briefly, the above document discloses a blow-moulding apparatus that comprises, further to the usual elements and components, a specially provided acoustical/electric transducer arrangement adapted to detect the noise issued outside by the individual moulds. And, the acoustical/electric transducer arrangement converts such a noise into an electric signal. Additionally, there are provided means that process this signal and compare it with a reference signal; provide means that, on the basis of the result of such a comparison, identifies burst or failed containers, as well as means that automatically and selectively exclude the burst or failed containers from the production line.

The apparatus described in the above-mentioned patent application has turned out as being actually capable of being implemented without any practical difficulty at all, as well as quite effective in blow-moulding bottles. However, practical experience on the production floor has caused some drawbacks (as noted below) to come to light, which for the matter are still being experienced with such a kind of apparatus.

A first drawback lies actually in the marked noisiness of the whole plant. As a matter of fact, these plants, especially when they are single-stage plants and, above all, when they are installed in an environment that includes other noisy industrial plants, are subject to a continuous, high-intensity acoustic stress from both the noise falling upon them from the outside and the noise that they generate themselves.

It has been found that, unacceptably too often, such a high noise level, which these plants are exposed to, can disguise the noise generated by a bursting preform (owing to the need for the intensity of the reference signal to be increased correspondingly), so that it fails to be detected and, as a result, the resulting defective product fails to be promptly removed from the production line, thereby making the detection arrangement of the described invention partially ineffective.

A second drawback is connected with the circumstance that the preform that reaches the blow-moulding station for being blown into the final product, is itself defective or damaged, thereby showing cracks that, however small , prevent the same preform from being blown into its final bottle shape due to the blowing gas leaking therethrough.

In this case, i.e. in the event of such failed blow-moulding operations due to already existing leaks in the preform, not even the typical noise generated by a bursting preform is actually generated, so that it is not possible for either the presence of a production reject to be identified or,

even less, the same production reject to be removed from the regular production flow.

In view of trying to find a remedy for these problems through the use of means for the detection of the pressure differences occurring whenever a preform being blow-moulded bursts, or in the event of a cracked preform failing to be blow-moulded, the solution has been considered of using suitable pressure detectors adapted to measure the pressure of the gas in the flow path followed by it when flowing into the container being blow-moulded. It has however been found that, when the bottles are being blow-moulded individually in a sequence, the pressure detector arrangement to be used must in that case be capable of withstanding very high pressures, up to approximately 40 bar, and at the same time measuring abrupt and marked pressure drops.

This is actually achievable with the use of industrial component parts that are currently available on the market; however, if the preforms, instead of bursting when being blown, are defective, i.e. cracked since the beginning,. the reduction in pressure that takes place in this case may be so small as to fail to be either detected at all, or detected regularly and unfailingly each time, by a pressure detector arrangement that has been provided in view of being capable of operating at far higher pressures or detecting total pressure drops. On the contrary, in the most usual and common case that a plurality of preforms are blow-moulded simultaneously from a single source supplying gas under pressure (i.e. the so-called in-line blow-moulding process), the pressure detector arrangement to be used must be capable of withstanding modest pressure variations taking place very rapidly. Further to the difficulty encountered in finding out such a suitable type of pressure detectors, the need also arises in this case for the fact to be considered that a pressure variation as measured in the gas supply conduit can be indicative of a blow-moulding die operating in an irregular manner, but fails to identify which mould is actually concerned.

## Summary of the Invention

It therefore is desirable, and it is actually a main object of the present invention, to provide an apparatus and a respective method that are capable of performing an automatic preform blow-moulding process and, at the same time, are provided with means that are capable of identifying in a substantially immediate manner those dies in which a preform is possibly blown to bursting, and keeping track of any so resulting reject so as to be able to put apart, in a fully automatic manner at an appropriate station through which the faulty preforms are due to pass, all such faultily blow-moulded preforms in the state of rejects.

In addition, the means must be capable of working without any limitation at all in a highly noisy environment and, at the same time, must also be capable of identifying those failed blow-moulding operations that substantially occur without generating any particular noise signals, such as in the case of already cracked preforms.

Such an apparatus and related method shall furthermore be reliable, fully efficient and operatively effective, as well as capable of being implemented through the use of readily available techniques and materials.

According to the present invention, these and further aims are reached in an apparatus and a method that are made and operate with the characteristics as recited in the appended claims.

## Brief Description of the Drawings

The present invention may be implemented in the form of a preferred embodiment that is described and illustrated in detail below by way of non-limiting example with reference to the accompanying drawings, in which:

- Figure 1 is a purely schematic view of an apparatus according to the present invention;

- Figure 1A is an enlarged, symbolical view of a section of the apparatus shown in Figure 1;

- Figure 2 is a diagrammatical view of the course of the internal pressure in a bottle during a regularly performed and occurring blow-moulding operation;

- Figure 3 is a diagrammatical view of a typical course of the differential pressure as detected during a blow-moulding operation in an apparatus of the kind illustrated in Figure 1, with a positive result of the same blow-moulding operation;

- Figure 4 is a diagrammatical view of the course of the differential pressure as detected during and after a blow-moulding operation in a same apparatus, in which the bottle being blown has burst;

- Figure 5 is a view of a first variant of the apparatus shown in Figure 1;

- Figure 6 is a view of a second improved variant of the apparatus shown in Figure 1;

- Figure 6A is a view of third improved variant of the apparatus shown in Figure 1;

- Figures 7 and 8 are diagrammatical views of the course of the differential pressure in the case of faulty preforms, in a situation similar to the one considered in Figure 4, but with an expanded pressure scale.

**Detailed Description of the Invention**

The present invention is essentially based on the observation that when, during the blow moulding of a preform, the latter undergoes tearing or breakage, one of the most immediate consequences of such an occurrence is a clearly perceptible and detectable explosion. That is due to the fact that the compressed air inside the preform being so blow-moulded escapes abruptly and violently through the leak so formed in the wall of the preform and causes a corresponding variation in the flow of air or gas being supplied into the preform itself to blow it into its final shape.

In order to more effectively describe this particular occurrence, reference is made to the illustration in Figure 2, which shows a diagram that has been plotted of the actual course of the pressure inside a preform being blown, or in the conduit of the air being supplied to such a purpose, during a blow-moulding operation performed and taking place in a regular and correct manner. There may be identified four main phases, wherein phase A refers to the preform being filled with gas supplied at low pressure, while almost simultaneously undergoing a stretching action that may take place either just before or just after the low-pressure gas supply is started. This phase therefore implies a significant flow of gas, and the perform is caused to blow up and expand into almost reaching the final shape of the bottle to be produced, while the pressure remains however at a low level.

In the following phase B, gas is let in at a quite high pressure, typically at approximately 40 bar, owing to the fact that the bottle, which at this point is almost moulded to its final shape, must be pressed against the blow-moulding die in view of being able to take its definitive, detailed shape.

Since this phase is carried out at an almost constant volume, the pressure inside the bottle builds up rapidly to reach its almost maximum value, while the flow decreases to the point it reaches almost zero.

In the next phase C, the high pressure inside the bottle is kept for a time as deemed necessary in view of enabling the bottle to stabilize and consolidate its definitive shape. The pressure is kept at its maximum value, while the gas inflow is practically zero (in the assumption that there are no leakages). In the final fourth phase D, the gas contained in the bottle is released therefrom, so that its pressure decreases rapidly to zero (atmospheric value).

It has been observed that, when a bottle turns out to be perforated, cracked or burst, at the end of the phase B and throughout the following phase C, inside the pipe that carries the air at 40 bar there is a substantial flow of gas, and it is actually this flow of gas that has desirably to be measured, since it is the most effective indicator of the existing air or gas leakage.

It has in fact been found that, if the bottle is not perforated, cracked or burst, such a flow of air tends to end up just after a very short time that the high-pressure air valve is opened.

If the bottle is on the contrary perforated, cracked or burst, or anyway there is a leakage indicative of an irregular blow-moulding operation, the high-pressure air flow keeps going on at a certain value, which is certainly detectable and may sometimes be also quite elevated, well beyond the duration of the phase C.

For the magnitude of the flow inside the supply conduit to be able to be determined in an accurate and reproducible manner, the need arises for a device and a related method to be provided, which do not alter pressure losses to any significant extent, are capable of withstanding static pressures of up to approximately 40 bar, and are resistant to the conditions imposed by working cycles that follow each other uninterruptedly within the conduit under turbulent flow conditions.

An apparatus provided with the device according to the present invention is comprised of following component parts (see Figure 1):

- a plurality of dies 100 for blow-moulding preforms,

- a main conduit 1 that carries the air into the cavities of the blow-moulding dies,

- a low-pressure gas supply source 103 connected to the main conduit 1 via a respective first supply channel 101,

- a suitably controlled valve 102 associated to the first supply channel,

- a high-pressure gas supply source 104 connected to the main conduit 1 via a respective second supply channel 105,

- a second suitably controlled valve 106 associated to the second supply channel.

In this example of embodiment, the invention includes providing the second supply channel 105 with a particular embodiment of a Pitot tube arrangement (which is widely known in the art, so that it shall not be described here any further). It is a largely known fact that such a device is capable of detecting and measuring even very low flow speeds: when a gas flows through the Pitot tube at a certain speed V, a pressure difference builds up across the tubes, on which this Pitot tube arrangement is based, such a pressure difference being proportional to the square of the speeds of the flow.

In this particular case, two small tubes 3, 4 are inserted in the supply channel 105, where they are arranged so as to extend across the channel orthogonally thereto. These tubes must be given as small a size as possible, so as to avoid adding any significant disturbance of the flow to

be measured; they must anyway be given a properly calibrated cross-section.

Both these small tubes have a respective bore 5, 6 extending along an axis aligned with the direction of the flow, but oriented in an opposite direction with respect to each other, i.e. the projection of a first bore 5 on a plane orthogonal to the direction of the flow, downstream of the same bore, is not nil, whereas nil is the projection thereof on the plane orthogonal to the direction of the flow, but upstream of the bore.

Exactly the opposite is true as far as the second bore 6 is concerned, as this is illustrated in Figure 1A.

Arranged in each one of the two small tubes there is a suitable pressure sensor 7 and 8, respectively, wherein the sensors are connected to a same differential pressure detector arrangement 10.

With the apparatus configured as defined and described above, a number of experiments have been carried out in order to identify the typical course of the differential pressure and, accordingly, of the speed of the flow of blowing gas, in the two opposite conditions of:

- regular blow-moulding with positive result (no leakage) and

- irregular blow-moulding with negative result (burst or perforation).

Figure 3 shows in a general manner a typical course of the differential pressure detected during blow moulding in a 16-cavity die, without any bottle bursting or breaking, whereas Figure 4 shows a typical course of the differential pressure as detected during and after a blow-moulding operation in a same apparatus, in which the bottle being blown has burst.

It clearly emerges from the illustration in Figure 3 that the differential pressure plotted on the ordinate, and therefore the flow, increases from an initial value of zero up to a maximum value, and then decreases again to the initial value of zero at the end of the blow-moulding process, and this can only be taken as an indication of a successfully blown bottle, since it is only in this case that the flow decreases progressively to zero during the total filling cycle.

In the opposite case, i.e. when a bottle bursts during blow moulding, as this is best illustrated in Figure 4, the differential pressure, and hence the flow, increases from an initial value of zero up to a maximum value $P_M$, and then decreases again to a value that anyway is higher than zero, i.e. $P_S > 0$, and this can only be taken as an indication of a bottle having burst during blow moulding, or anyway leaking, since it is only in this case that the flow may well decrease during high-pressure gas blowing, but will never reach down to zero.

Owing to the rather small-scale representation in Figure 4, in order to be able to take a closer look at and more accurately follow the course of the pressure as detected in some similar cases, in which the bottles have burst during blow moulding, some experiments have been reproduced. The results of the experiments are illustrated in Figures 7 and 8, in which the vertical or pressure scale is expanded. In particular, Figure 7 indicates the course of the typical $\Delta P$ of a bottle that, while not burst, is punctured, whereas Figure 8 indicates the typical $\Delta P$ of a bottle that has burst.

Going on with the investigation of such phenomena, it has been most clearly observed that, in each one of the cases represented in the above cited Figures, it is possible to identify a positive (i.e. higher than zero) average differential pressure, which is assumed as being the reference differential pressure P1, associated to and persisting over a certain definite period of time T1 after the beginning of the blowing phase; defined is then most suitably also a maximum threshold value P2 of the

differential pressure, to which conventionally corresponds a decision whether there is a leakage during blow moulding or not.

When the differential pressure being measured at that definite moment, or even during a pre-established period of time, exceeds the pre-established maximum threshold value of differential pressure P2, it can then be concluded with a reasonable level of confidence that the blow-moulding operation has failed to be completed successfully due to the existence of more or less marked gas leakages or losses.

Going back at this point to Figure 1A, the differential pressure detector arrangement 10 is connected to an appropriate processing means 11, which is capable of receiving the signals coming from the differential pressure detector arrangement 10, measuring the value thereof, receiving and storing reference levels set by the external operator, comparing the values with the reference levels and, based on the outcome of such a comparison, generating appropriate command and control signals to be sent to further actuation means (not shown), which are made and arranged in an appropriate manner so as to be able to exclude, i.e. remove from the production process those bottles which are told to be defective by the outcome of the comparison.

These operations and means for processing electric and electronic signals, as well as comparing and producing control and actuation signals are fully and readily available to and within the capability of all those skilled in the art of industrial automation, so that they shall not be described in any greater detail here.

The described invention may furthermore be embodied so as to include following advantageous improvements: with reference to Figure 5, the two tubes 51 and 52, in which there are provided respective ports 53 and 54 with related pressure detectors 55, 56 connected to the differential pressure detector arrangement 10. The respective ports are substantially

positioned in the same section of the high-pressure gas supply channel 105 so as to simplify the construction and perturb the regular flow conditions of the blowing gas in the conduit to an even lesser extent.

A further improved and simplified embodiment of the present invention is shown in Figure 6, in which the two ports 60 and 61 are provided in a same tube 62 extending across the high-pressure gas supply channel 105. These ports must of course be provided in two chambers that are isolated from each other as far as pressure is concerned. For this reason, inside the same tube 62 there is provided a partition wall 63 that isolates from each other the chambers in which the two ports 60 and 61 and the related pressure detectors (not shown). It will of course be appreciated that the partition wall 63 may be assigned various forms and shapes, as shown also in Figure 6A, without affecting the validity and effectiveness of the present invention.